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Under Secretary of Commerce
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Attorney Docket No. GRA26 029

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Sir:

Transmitted herewith for filing is the PROVISIONAL APPLICATION

for a patent of Inventor(s):

MARTIN ALLES, JOSEPH P. KENNEDY, JR., and JOHN CARLSON

Title: SYSTEM AND METHOD FOR IDENTIFYING THE PATH OR DEVICES ON THE PATH OF A COMMUNICATION SIGNAL USING (l+r(t)) AMPLITUDE MODULATION

Enclosed are:

[X] A Cover Page and Three (3) pages of specification.

[X] A check in the amount of $160.00 to cover the filing fee.

The Commissioner is hereby authorized to charge payment of any additional fees associated with this communication or to credit any overpayment to Deposit Account No. 04-1679. A duplicate of this sheet is enclosed.

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SYSTEM AND METHOD FOR IDENTIFYING THE PATH OR DEVICES ON THE PATH OF A COMMUNICATION SIGNAL USING (1+r(t)) AMPLITUDE MODULATION

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Repeater Watermarking using (1+r(t)) type Amplitude Modulation

1.0 - Engineering concepts for watermark implementation at a repeater

Introduction:

This proposal is to address the issue of repeater identification via the signal insertion of a signal dependent co-channel signal in active channels. This co-channel signal is generated by applying a specific form of Amplitude Modulation (AM) to the entire repeated signal bandwidth, and serves as a watermark that identifies a mobile using a particular repeater station. The magnitude of the co-channel signal as well as any adjacent channel interference caused by the AM process can be controlled in magnitude. When no signal is present, the AM process generates a signal buried deep within the noise. When a signal is present, the co-channel signal can be used to uniquely identify the repeater. The latter signal may also be buried in the noise by appropriate engineering.

Description of operations needed at the repeater:

The wideband signal w(t) constituting the signal to be repeated at the repeater is AM modulated at the repeater using a narrowband signal of the form (1+r(t)). The AM modulated signal is then subject to any pre-existing scheme of repetition used at that repeater (generally expressed as a delay on the signal followed by an amplification).

The mathematical effect of this form of modulation is to generate a co-channel signal w(t)r(t) in the repeater bandwidth. The "1" in the term "(1+r(t))" simply replicates the primary signal (the mobile signal). Since AM modulation is equivalent to multiplication, the modulation can also be viewed as multiplication of w(t) by the function (1+r(t)). Figure 1 illustrates the method of implementation where the operations are performed on a digitized signal at the repeater. The digitized signal represents the entire bandwidth operated on by the repeater.

To illustrate the concept further, consider a particular narrowband channel. In that channel, if there was an active mobile call using signal s(t) in progress, the co-channel signal generated by the AM process will be of the form s(t)r(t). If the channel were inactive, the co-channel signal will be of the form n(t)r(t) where n(t) is noise. By suitably controlling the norm (or average amplitude) of r(t), the magnitude of the co-channel component can be maintained at a much reduced power level with respect to the primary mobile signal s(t). Further, any spectral spillage into adjacent bins can be reduced below the noise power level in those bins by suitably manipulating the amplitude of r(t). In fact, by controlling the amplitude of r(t), we can make both the co-channel signal component and the adjacent channel interference as large as or as small as desired. The amplitude control is determined based on the relative power desired between the primary signal s(t) and the co-channel component. After the proper determination is made, this amplitude is fixed at the repeater during operation.

If the signal at the repeater is processed digitally, the digital samples representing the repeater bandwidth are multiplied by the waveform r(t) and added back to the signal. The amplitude of the waveform r(t) (assumed constant modulus or nearly so) then automatically determines the magnitude/power of the watermark signal. Thus, by controlling the amplitude of the signal r(t) in the digital operations at the repeater, the inserted co-channel component defining the watermark can be power controlled. It is expected that this amplitude will be pre-computed and implemented so that the co-channel watermark signal is buried in the noise.

Thus, for example in an active cellular channel, the introduced repeater identification signal can be at a power level 20dB or lower than the primary signal, whereas in an inactive channel, the repeater identification signal will be 20dB or lower than the pre-existing noise in that channel. In every channel, the corresponding repeater signal is at a power level 20dB or lower than the pre-existing signal level in that channel. The 20dB value is chosen simply to quantify the concept and any other dB number can be picked with equal applicability, and implemented via the specified amplitude used for r(t) in the digital signal processor.

For a given mobile signal s(t), it is apparent that the signal r(t) is what distinguishes the particular repeater. Thus each repeater has a unique narrowband waveform r(t).

The collection of such waveforms r(t) over a set of repeaters, denoted S, may be drawn from sets of waveforms with specific properties. For example the set S may be orthogonal, quasi-orthogonal, or shift orthogonal. The properties of the waveforms r(t) used to generate the set S will, among other things, depend on the number of repeaters implemented in a cellular system cell or sector. A good set that we have used in extensive simulations is the set of 26 waveforms in a Golay-Hadamard codebook, derived from complementary Golay sequences.

The repeaters may either apply their identifying signals synchronously or asynchronously. A synchronous approach would require the repeaters to operate in unison with an extraneous clock but would provide greater discrimination of the repeater at the receiver. For ease of operation, it is expected that the identifying signal will be applied asynchronously, so that each repeater station will operate independent of all other stations, and independent of any extraneous control.

The repeaters should also apply their identifying signals in a repetitive loop so that the waveforms r(t) cycle over and over again (repeat). Thus the signal r(t) can be envisioned as the output of a cyclic shift register. The bandwidth of these waveforms will typically be of the order of 30kHz.

In Figure 1, w_k is the digitized repeater input, r_k is the repeater identification waveform and w_k' is the repeater output sample.

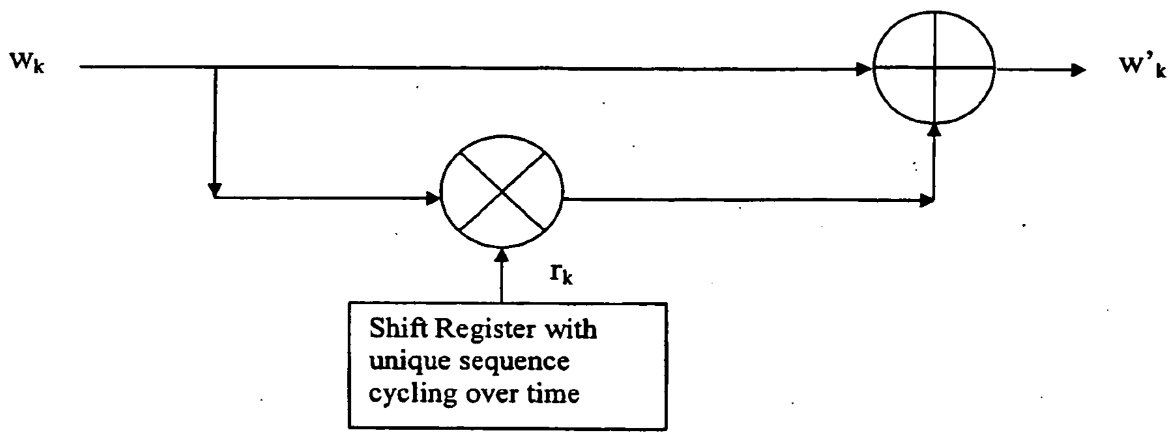

Figure 1: Digital Operations for watermark implementation